

The role of seasonality in lettuce consumption: a case study of environmental and social aspects

Almudena Hospido · Llorenç Milà i Canals ·
Sarah McLaren · Monica Truninger ·
Gareth Edwards-Jones · Roland Clift

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Abstract

Background, aim and scope Considerable debate surrounds the assessment of the environmental impacts and the ethical justification for providing a year-round supply of fresh produce to consumers in the developed countries of northern Europe. Society is seeking environmentally sustainable supply chains which maintain the variety of fresh food on offer throughout the year. This paper compares the

environmental impacts of different supply chains providing lettuce all year round to the UK and considers consumers' meanings of—and attitudes to—available options. Lettuce has been selected as a case study as its consumption has grown steadily during the last two decades and the supply chains through cold months are protected cropping in the UK and field cropping in Spain; during warm months, lettuce is sourced from field cropping in the UK.

Materials and methods Data were collected from farms supplying each of these supply chains, and life cycle assessment methodology was used to analyse a range of impacts associated with producing (from plant propagation to harvesting and post-harvest cooling) and delivering 1 kg of lettuce to a UK Regional Distribution Centre (RDC). The downstream stages (i.e. retailing, consumption and waste management) are the same regardless of the origin of the product and were omitted from the comparison. The impacts considered included potential to induce global warming and acidification as well as three inventory indicators (primary energy use, land use and water use). Qualitative data were collected in order to assess the consumer considerations of purchasing lettuce also during winter.

Results Importation of Spanish field-grown lettuce into the UK during winter produced fewer greenhouse gas (GHG) emissions than lettuce produced in UK-protected systems at that time (0.4–0.5 vs. 1.5–3.7 kg CO₂-eq/kg lettuce in RDC). Refrigerated transport to the UK was an important element of the global warming potential associated with Spanish lettuce (42.5% of emissions), whilst energy for heating dominated the results in UK-protected cultivation (84.3% of emissions). Results for acidification were more variable and no overall trends are apparent. Results from qualitative social analysis revealed complex and multidimensional meanings of freshness and suggested that the most striking seasonal variation in vegetable/salad eating

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A. Hospido · L. Milà i Canals · S. McLaren · R. Clift
Centre for Environmental Strategy, University of Surrey,
Guildford GU2 7XH, UK

M. Truninger
Institute of Social Sciences, Lisbon University,
1600-189 Lisbon, Portugal

G. Edwards-Jones
School of the Environment and Natural Resources,
Bangor University,
Bangor, Gwynedd LL57 2UW, UK

Present Address:
A. Hospido (✉)
Department of Chemical Engineering,
University of Santiago de Compostela,
15782 Santiago de Compostela, Spain
e-mail: almudena.hospido@usc.es

Present Address:
L. Milà i Canals
Unilever, Safety & Environmental Assurance Centre,
Colworth Park,
MK44 1LQ Sharnbrook, Bedfordshire, UK

Present Address:
S. McLaren
Sustainability and Society, Landcare Research,
P.O. Box 40, 7640 Lincoln, New Zealand

was a tendency to consume more salads in the summer and more cooked vegetables in the winter, thus suggesting that in-home consumption alone cannot explain the rise in winter imports of lettuce to the UK.

Discussion UK field-grown lettuce had the lowest overall environmental impact; however, those lettuces are only available in summer, so consumers therefore need to either accept the environmental impacts associated with eating lettuce in the winter or to switch consumption to another food product in the winter. When lettuces were field-grown in Spain and then transported by road to the UK, the overall impacts were similar to the UK field lettuces. The variation within farms of the same country employing different cultivation regimes and practices was bigger than between farms of different countries.

Conclusions This paper has explored the environmental consequences of consuming lettuce year-round in the UK. Whilst recognising the small sample size, the comparative analysis of the different supply chains does suggest that seasonality can be an important variable when defining the best choice of lettuce from an environmental point of view.

Recommendations and perspectives Further studies considering more production sites and product types are required to obtain conclusions whose general validity is clear and for different types of fresh produce. A clear distinction to be made in such studies is whether crops are produced in open fields or under protection. New characterisation methods are needed for environmental impacts derived from the use of key agricultural resources such as land and water. Social studies to investigate consumer preferences and the possibility of moving to more seasonal diets should be an integral part of these studies using samples composed of both urban and rural consumers and using a mixed methodology with both quantitative and qualitative components.

Keywords Consumers' meanings and attitudes · Food miles · Fresh produce · LCA · Life cycle assessment · Lettuce · Seasonality

1 Background, aim and scope

Patterns of food production, distribution and consumption have undergone major transformations over the past half century. One of the consequences of these changes is that consumers have become used to the availability of an increased range of produce in shops regardless of the natural seasonality of its production. Indeed, recent research suggests that over 70% of consumers in UK urban areas expect to be able to purchase fresh vegetables and salad items at any time of the year.¹

¹ Dr. Barry Hounsome, Bangor University. Personal communication, November 2006.

This level of demand has led to increased intercontinental transport of food produce, and as a result, there have been increased concerns about the environmental and social impacts of this global trade (Fortescue 2005; Hamilton 2006). The concept of food miles has been prominent in this debate (Smith et al. 2005), and a series of studies have sought to compare the environmental impacts of food from local and distant production systems (e.g. Blanke and Burdick 2005; Jungbluth and Demmeler 2005; Schlich and Fleissner 2005; Milà i Canals et al. 2007a; Sim et al. 2007).

To date, these debates have tended to focus around the transport of fruit and vegetables (Edwards-Jones et al. 2008a), which is a sector of particular concern for north European countries that are unable to grow vegetables all year round due to climatic constraints. This situation is compounded by the fact that many vegetables have limited shelf life. In order to overcome the natural seasonality of supply in northern Europe, four basic strategies have been adopted by industry: protected cultivation to produce out-of-season; controlled storage to supply out-of-season; importation of fresh produce from countries where it is in season; and consumption of alternative vegetables that are in season (NB for the purposes of this paper, "controlled storage" refers to a minimum of 4 weeks' storage, i.e. the cold chain required simply to preserve produce along the supply chain for a matter of days is not considered here. Drying, preserving and canning are also not considered because the processed product is no longer considered 'fresh').

In the specific case of lettuce, modern cooling technologies are being developed and used to extend storage life. Vacuum cooling is used commercially in the USA and many European countries, particularly for iceberg lettuce, and when combined with cold storage, it can extend shelf life from 3–5 days up to 2 weeks at 1°C (Artes and Martinez 1995, 1996, cited in Sun and Zheng 2006) or even up to 40 days at 0°C (Kim et al. 1995, cited in Brosnan and Sun 2001). Nevertheless, these techniques are not yet universally adopted, and as a result, the average shelf life of lettuce is normally considered to be around 1 week. Protected cultivation of lettuce, on the other hand, is a traditional winter supply option in northern Europe and therefore represents an alternative to importing fresh produce from warmer countries. Potential alternatives to lettuce include winter crops that may be used in salads, such as white or red cabbage (which may be stored at cool or ambient temperature for several months) and chicory (which is stored frozen as a root and 'forced' in dark chambers through the year in response to demand).

It is important to identify the most environmentally friendly supply chains for lettuce, as during the period 1985–2005, lettuce consumption in the UK grew steadily from 40 to 60 g of lettuce per person per week (DEFRA 2006, 2007; Fig. 1). Against this background, this paper explores the following questions: What are the environ-

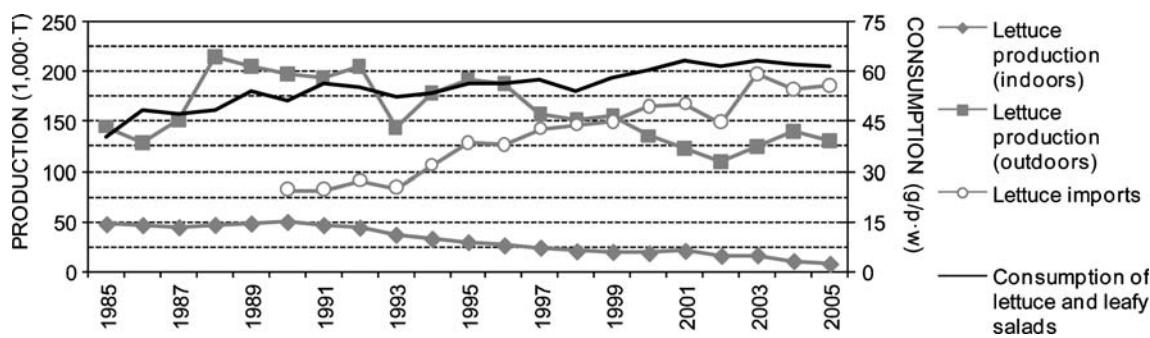


Fig. 1 Production (in thousands of tonnes) and consumption (in grams per person and week) of lettuce in the UK (DEFRA 2006, 2007)

mental impacts of supplying lettuce to British consumers from alternative supply chains at different times of the year? What are the activities that contribute most to the environmental impacts of providing 1 kg of lettuce to the British consumer? Are lettuces supplied from alternative supply chains regarded as equivalent by consumers? What are the environmental impacts and social acceptability of consuming alternatives to lettuce?

In order to address these issues, this paper reports and discusses the results of: (a) life cycle assessments (LCA) of seven farms that operate early and/or late cropping systems, protected and/or unprotected production and are located in either the UK or Spain and (b) a qualitative social study of rural consumers' meanings and attitudes towards locally produced vegetables, their eating patterns of vegetables throughout the year, views about eating salads out-of-season and what alternatives they perceive as substitutes to lettuce.

2 Materials and methods

2.1 System under study

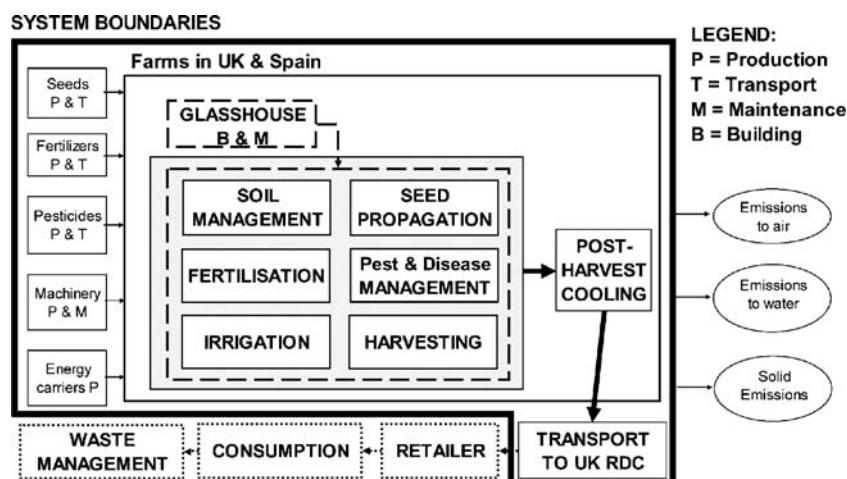
The system has been defined in accordance with recommended approaches for comparing domestic with imported

food (Jungbluth and Demmeler 2005; Milà i Canals et al. 2007a; Edwards-Jones et al. 2008a), and the processes considered in the study are shown in Fig. 2.

A large retailer perspective was adopted because large retailers supply 80% of fresh produce in the UK (Blythman 2004). Major retailers use Regional Distribution Centres (RDC) so that downstream stages (i.e. retailing, consumption and waste management) are the same regardless of the origin of the product and may therefore be omitted from the comparison. Therefore, the scope of the study was cradle-to-RDC; different results may be expected for more localised distribution, such as farm shops or farmers' markets, because of the differences in the distribution networks (e.g. van Hauwermeiren et al. 2007) and the scale of processing facilities (e.g. Andersson and Ohlsson 1998; Sundkvist et al. 2001).

The systems analysed extend from plant propagation to the RDC, including all farm operations (soil management, fertiliser use, planting, pest and disease management, irrigation, harvesting and post-harvest cooling). Building and maintenance of glasshouses for indoor production of lettuce were included as they represent a specific characteristic of protected cultivation. Farm machinery production and maintenance were also considered, following normal practice in agricultural LCA (Audsley et al. 1997; Nemecek

Fig. 2 Activities included in the system under study and definition of its boundaries



et al. 2004). The analysis considered lettuce sold loose and no packaging production was considered.

2.2 Functional unit

The functional unit (FU) was 1 kg of lettuce delivered to a UK RDC. The data used in the study were obtained for production of cos, iceberg and green oak leaf lettuces and fine endives, but no distinction was made on the basis of lettuce variety or nutritional content. Different producers grow lettuces to different sizes depending on customer requirements, thus affecting yields. The yield reported by the farmer was utilised regardless of whether it could have been potentially higher or lower had a different size been harvested.

2.3 Data collection

Between 2006 and 2008, vegetable farms in the UK and Spain were invited to participate in a wide ranging research project to establish LCA and economic data to explore issues related to the production of 'local' and 'non-local' food (Edwards-Jones et al. 2008a). Participating farms assisted in collection of data covering greenhouse gas emissions, soil quality and nutritional quality of the produce and in social and economic studies. The sampling strategy, further described elsewhere (Edwards-Jones et al. 2008b), was opportunistic as initially, all commercial horticultural farms in specific regions (Lincolnshire, Hereford and Worcester in UK and Murcia in Spain) were approached by a letter followed up with a phone call. The purpose of the project was explained to the farmer in these communications, and interested farms were then visited by project staff for further discussion. Collection of experimental data required regular visits to the participating farms over this period.

This sampling procedure was pragmatic as it ensured good coverage of regions within a country and also ensured farms were clear as to their commitment to the project. However, it was not a statistically representative sample of farms in these regions. So, whilst the sample farms appeared to be qualitatively typical of their type, the results cannot be extrapolated to all farms in a region or country. The data reported here relate to on-farm production practices, post-harvest cooling and transport to the RDC in the UK. They were gathered directly from individual producers in the UK (three for open field: referred to as UKa, UKb and UKc; two for under-glass: UKc-In and UKd-In) and Spain (two producers: ESa and ESb).

Through discussion with farmers and other relevant actors, it was possible to identify the entire supply chain(s) which linked their production to retail. Discussions with the various bodies involved in the entire supply chain provided additional information on technical issues and supplied data for the LCA and other analyses.

Data relating to the production of ancillary products (fertilisers, pesticides, fuels, farm machinery, electricity, etc.) come from the Ecoinvent 1.2 database (Frischknecht et al. 2004). Field nutrient emissions were calculated following Audsley et al. (1997) and Nemecek et al. (2004). An extensive literature review for annual crops in France (Arrouays et al. 2002) suggested that CO₂ emissions from soil organic matter degradation corresponded to a net loss of 0.4±0.08 t C ha⁻¹ year⁻¹.

For the comparison with alternative crops, data on chicory production were gathered from a farm in the UK, and estimates for cabbage production were interpolated from primary data for production of broccoli, a very similar crop grown on two farms in the UK (Milà i Canals et al. 2008).

2.4 LCIA method and impact categories

The CML 2001 method (Guinée et al. 2002) was used for impact assessment. Results for two dominant impact categories [global warming potential (GWP) and acidification (AP)] are complemented by results for three inventory indicators relevant to this particular product group: primary non-renewable energy use (PEU, measured in MJ), land use (LU, measured in m²·year) and water use (WU, measured in litres). Eutrophication was omitted from the analysis as no site-specific information was available.

LU and WU, in particular, need further characterisation for proper interpretation, e.g. to incorporate the effects of different land management practices on soil quality (Milà i Canals et al. 2007b) or the source and regional scarcity of water (Milà i Canals et al. 2009), but they are included here for illustration. Generally, toxicity impacts tend to be dominated by pesticide emissions in horticultural LCA studies (Margni et al. 2002; Antón et al. 2003; Milà i Canals et al. 2006; Hauschild et al. 2007), and these have not been detailed in this analysis; see Cross and Edwards-Jones (2006) for further discussion.

2.5 Consumers' meanings and attitudes towards vegetables and salad items

Qualitative data concerning rural consumers' meanings and attitudes towards vegetables and salad items were collected in two different stages between 2006 and 2007 in order to assess considerations regarding purchase of lettuce during the winter and also the meanings of the specific quality criteria they attribute to salads, notably freshness. The first stage comprised running seven focus groups with consumers living in three different areas in the UK (Anglesey, Herefordshire and Lincolnshire). In the second stage, 50 in-depth interviews with consumers living in the same areas were conducted. Both focus groups and interviews were selected

through a purposive sample built according to criteria such as: region, age, gender, income and women with children.

In both stages of data collection, the interview schedules were loosely structured around a set of questions relating to the meanings of local food, general shopping experiences, attitudes to eating seasonally, attitudes to lettuce substitution, attitudes to polytunnels, food memories, vegetable home growing, cooking practices, attitudes to storage and disposal of vegetables and criteria for choosing which vegetables to purchase. All interview material was analysed through content analysis, which is based on the examination of the data for recurrent themes or instances that are then systematically identified across the data set (Wilkinson 2004). To assist in the analysis, the software package NVivo 7 (non-numerical unstructured data for indexing, searching and theorizing) was used. This tool helps to conduct a rigorous and systematic approach to data analysis, coding and interpretation.

3 Results

3.1 Lettuce supply systems

The principal supply chains providing lettuce for domestic consumption in the UK throughout the year are shown in Table 1. Open field production in the UK provides supply from May to October, whilst lettuce is imported, primarily from Spain (around 80%), during the rest of the year. Protected cropping makes some domestic lettuce available throughout the year.

These systems are represented in the sample farms as an early grown field crop (UK-1) and later crops (UK-2); these crops were grown on UK farms a, b, c. Protected cropping, in glasshouses (UK-In), occurred in UK farms c and d, although farm c only produces indoors from September to May, whilst farm d produces indoors year-round. In Spain, both farms (a and b) provided both early (ES-1) and later crops (ES-2). Ranges of yields for each supply chain is presented in Table 1 and detailed information on the LCA studies performed at each farm can be found in Milà i Canals et al. (2008).

Outdoor production practices change throughout the season in response to weather conditions, e.g. UK early crops (harvested May to mid July) are protected with fleece to prevent frost damage during the first 6 weeks in the field, and water consumption is higher in later months, whilst early Spanish crops (planted in August–September) generally require more water for irrigation.

² Average value (years 2000–2005) for the item 0705: LETTUCE ‘*Lactuca sativa*’ and CHICORY ‘*Cichorium spp.*’; fresh or chilled. Source: <http://www.uktradeinfo.com/> (last accessed: 10/04/2006).

Farm UKa was a large farm, oriented mainly to producing salad crops. Most operations were highly mechanised (around 50 tractor hours per crop), apart from those which could only be performed manually, such as harvesting. Some hand-weeding helped reduce herbicide input. Integrated pest control had been adopted, and mineral fertiliser applications were tailored specifically for each field following soil analyses. The farm had on-site facilities for cooling and packing salad crops. Farms UKb and UKc were similar to UKa in terms of business orientation, although smaller in scale. The approach to nutrient management and pest control was similar, as was the level of mechanisation (30–50 tractor hours per ha per crop). However, these farms used smaller machines with lower fuel consumption: around 465 and 240 l of diesel per crop compared to over 550 in UKa. Farm UKd produced under glass all year round; thus, land use efficiency was very high, and the use of mineral fertilisers was lower than on other British farms.

The Spanish farms had greater inputs of pesticides, fertilisers and water than their British counterparts. The slightly higher pesticide input was partly due to higher pest and disease incidence and partly due to the prophylactic use of certain chemicals. In the case of fertilisers, higher doses were applied to overcome the nutrient fixation in the basic soils of Spain (particularly in ESa); in addition to mineral fertilisers, significant amounts of animal manure were applied to each crop. The Spanish farms used slightly lower planting density than those in the UK, although the yields tended to be greater due to harvesting bigger lettuce heads. Both Spanish farms had lower levels of mechanisation than the British farms, with 22 and 15 tractor hours per crop, respectively. However, ESa had large tractors and its fuel consumption was in the range of some of the UK farms: 250 l per crop compared to approximately 150 l in ESb. The lower use of tractors can probably be explained by high labour inputs on Spanish farms. Unfortunately, human labour was not quantified in the UK, and thus, a direct comparative value cannot be given. Workers’ transport-related fuel consumption was quantified in the Spanish farms (Milà i Canals et al. 2007c), but in both farms, it was negligible compared to total use by tractors: approximately 8 and 13 l per crop in ESa and ESb, respectively.

3.2 Analysis of contribution

The relative contributions to GWP of emissions from the different activities in lettuce production are shown in Fig. 3. Outdoor cropping had similar contributions from the different activities for both British (see Fig. 3a) and Spanish (see Fig. 3b) crops, with a higher contribution from transportation for Spanish lettuce due to the longer distance travelled to the RDC. Fertiliser use is one of the main sources of GHG emissions in both countries, mainly due to

Table 1 Sources and range of yields of lettuce for UK consumption through the year (UK-1 = early UK outdoor production; UK-2 = late UK outdoor production; UK-In = UK year-round protected production; ES-1 = early outdoor production in Spain and ES-2 = late outdoor production in Spain)

	J	F	M	A	M	J	J	A	S	O	N	D	Ranges of yields (kg/ha·crop)
UK-1					X	X	X						15,446–27,200
UK-2							X	X					20,000–27,200
UK-In	X	X	X	X	X	X	X	X	X	X	X		48,864–67,556
ES-1									X	X	X		36,000–36,100
ES-2	X	X	X	X									30,000–36,100

fertiliser manufacture and to direct emission of nitrous oxide (N_2O). As noted above, cropping is more intensively mechanised in the UK, thereby leading to higher GHG emissions associated with fuel use. Energy use for irrigation was higher in Spain due to slightly higher water consumption, with water being pumped from deeper underground.

In the case of indoor production, CO_2 emissions from natural gas combustion to heat the glasshouses totally dominate the impact (90.5%; see Fig. 3c). However, under summer conditions, when heating was not required (see Fig. 3d), the contribution of post-harvest cooling was more significant due to the high electricity consumption for lettuce cold storage.

Fertiliser use represented a major source of AP: Direct emissions of NH_3 dominate this impact category for UK outdoor production. However, in the case of the Spanish farms, the highest contribution to AP was shared between fertiliser use and refrigerated transport to the RDC. In protected cropping, energy-related emissions from heating under winter conditions and post-harvest cooling under summer conditions were the most important acidifying processes.

3.3 Comparative analysis

The total GWP from UK indoor production in winter (November–April) is substantially greater than from UK and Spanish field production (Fig. 4a), primarily due to the

energy required to heat the glasshouses over winter. When heating is required, growing lettuce releases more than 1 kg CO_2 -eq. per FU (3.73 at UKd-In and 1.51 at UKc-In-W). Indeed, high energy use and rising energy prices partly explains why many British indoor lettuce growers have discontinued production and often act as importers during winter. It is also interesting to note that the emissions from the Spanish farms in these months are lower than the UK-produced lettuce, even though the Spanish lettuce is transported by road from Murcia to the RDC, because the emissions from transport are lower than those associated with heating and lighting greenhouses in the UK. During the summer months, the overall level of emissions from the UK field-produced lettuce is similar to that of the Spanish lettuce grown in winter, even when the emissions from transporting Spanish lettuce over 2,600 km are included, due to lower mechanisation and higher yields on Spanish farms (Milà i Canals et al. 2008). Taken together, these results provide a clear illustration of a general conclusion that local food is not necessarily more “environmentally friendly” than imported food.

Whilst these results are interesting, it is important to note the qualitative differences in the data gathered for the two UK-protected cropping farms (UKc-In and UKd-In). Unfortunately, UKc-In did not record on-site usage of natural gas consumed for heating of greenhouses, and bibliographic data were used, specifically the typical values for annual energy use in extensive edible crop production

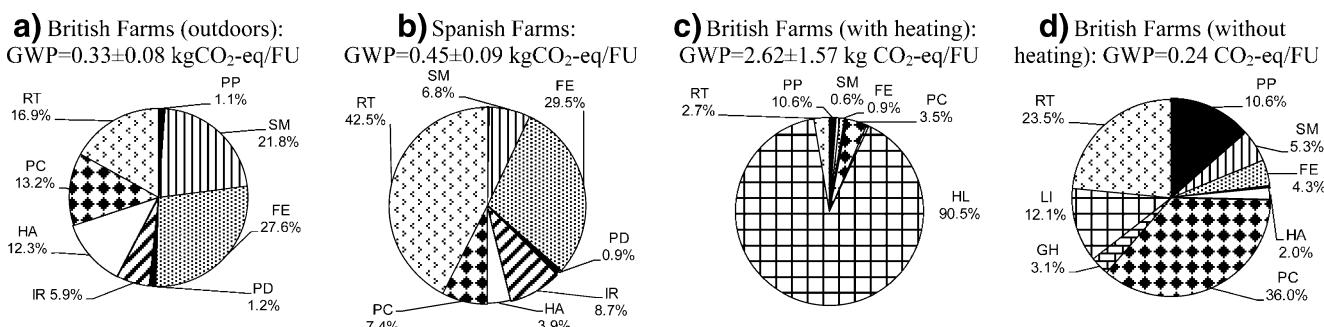


Fig. 3 Distribution of the GWP generated by lettuce production (average contributions). PP plant propagation, SM soil management, FE fertilisation, PD P&D management, IR irrigation, HA harvesting,

PC postharvest cooling, RT refrigerated transport, HL heating&Lighting, LI lighting, GH glasshouse Building&Maintenance. Those activities with an input of <0.5% are not displayed

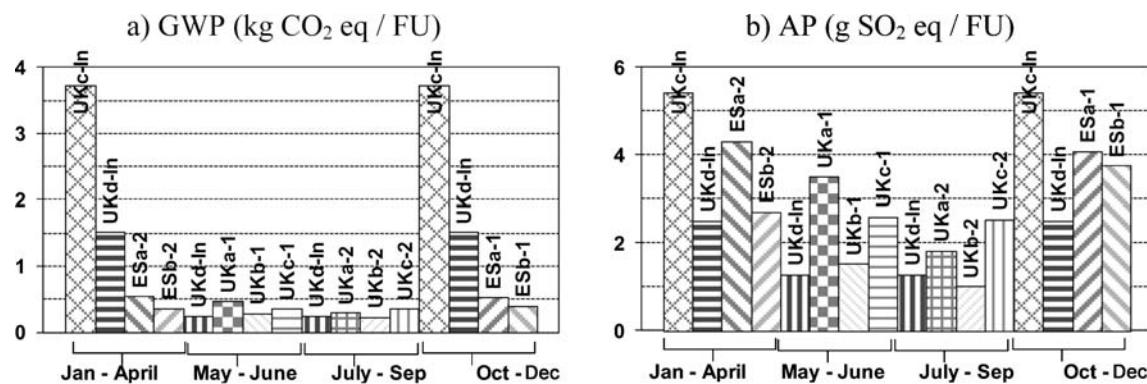


Fig. 4 Comparative results for the impact categories of the studied suppliers: **a** GWP (kg CO₂ eq/1 kg of lettuce delivered to the RDC), **b** AP (g SO₂ eq/1 kg of lettuce delivered to the RDC)

reported by The Carbon Trust (2004): 250 kWh/m² of heat (natural gas) and 12 kWh/m² of electricity. However, farm UKd-In did provide measurements of the energy used annually for heating and lighting in winter and summer, showing much lower contributions to GWP than the Carbon Trust estimates. This raises important issues about the relevance of using standard data and actual on-farm data for LCA and carbon footprints of agricultural products. In any case, regardless of using data from farm UKc-In or from farm UKd-In, the overall pattern of emissions remains the same, with UK-protected cropping leading to higher GHG emissions than the imported Spanish lettuce.

AP shows a large level of variation between the farms (Fig. 4b). This variation largely arises due to the types and amounts of energy used and the fertilisers applied. As a result, no overall trends are apparent, although field production of lettuce in the UK seems to have lower acidification potential than does either of the supply chains which provide lettuce in the winter.

Road transportation to the UK accounts for 40–50% of PEU in Spanish lettuce (Fig. 5a), although overall PEU is not much larger for Spanish imports than for British summer-grown lettuce. Not surprisingly, the protected cropping systems are by far the most primary energy-intensive.

Analysis of LU (Fig. 5b) is dominated by the agricultural stage. However, it should be noted that 4–6% of the land used through the lettuce's life cycle stages is sealed or otherwise heavily transformed (e.g. roads, buildings, etc.) and could therefore arguably be weighted more heavily in a characterisation step. Glasshouses are used more intensively than open fields (e.g. UKc-In and UKd-In produced three and five crops per year, respectively), and therefore, the values for LU in indoor production are lower than for outdoor.

The sources of water differ: Both Spanish farms use groundwater, whilst UKa and UKd use grid water and UKd and UKc use river water. The highest levels of WU were

observed in the Spanish farm ESb-1, which supplied lettuce to the UK in the winter months (Fig. 5c). This is because some of this lettuce would have been planted during the hot months of August and September and thereby received more than twice as much irrigation water as British indoor production. However, the water consumption per hectare differs widely between farms; the reason for this was not identified. UK production over summer (second crop) also required more water than both the first field crop and the indoor production.

Electricity use to pump irrigation water is higher per cubic metre in Spain than in the UK (1.1 compared to 0.15–0.35 kWh/m³ in the UK) due to the fact that in Spain, this is often groundwater and it must, on some occasions, be pumped from deep aquifers (over 100 m deep).

3.4 Alternative crops

Preliminary analysis of the environmental impacts arising from potential alternatives to winter lettuce suggests similar magnitudes to those associated with imports from Spain. For example, the PEU required to supply 1 kg chicory (after 5.5 months of storage) and cabbage (after 5–7 months storage) is around 10 and 2–3 MJ/kg, respectively, compared to approximately 5–7 MJ/kg for Spanish imports and 30–80 MJ/kg for UK-based protected cropping over winter. However, it must be noted that consumers do not seem to perceive such crops as real alternatives to lettuce, as further explained in Section 3.5.

3.5 Consumers' meanings and attitudes

LCA studies to compare alternative systems or products need to establish the substitutability of the alternatives compared. Particularly for food, this requires systematic assessment of consumers' views and priorities. In parallel with the LCA work, a qualitative study was carried out involving consumers in rural areas in the UK. One of the

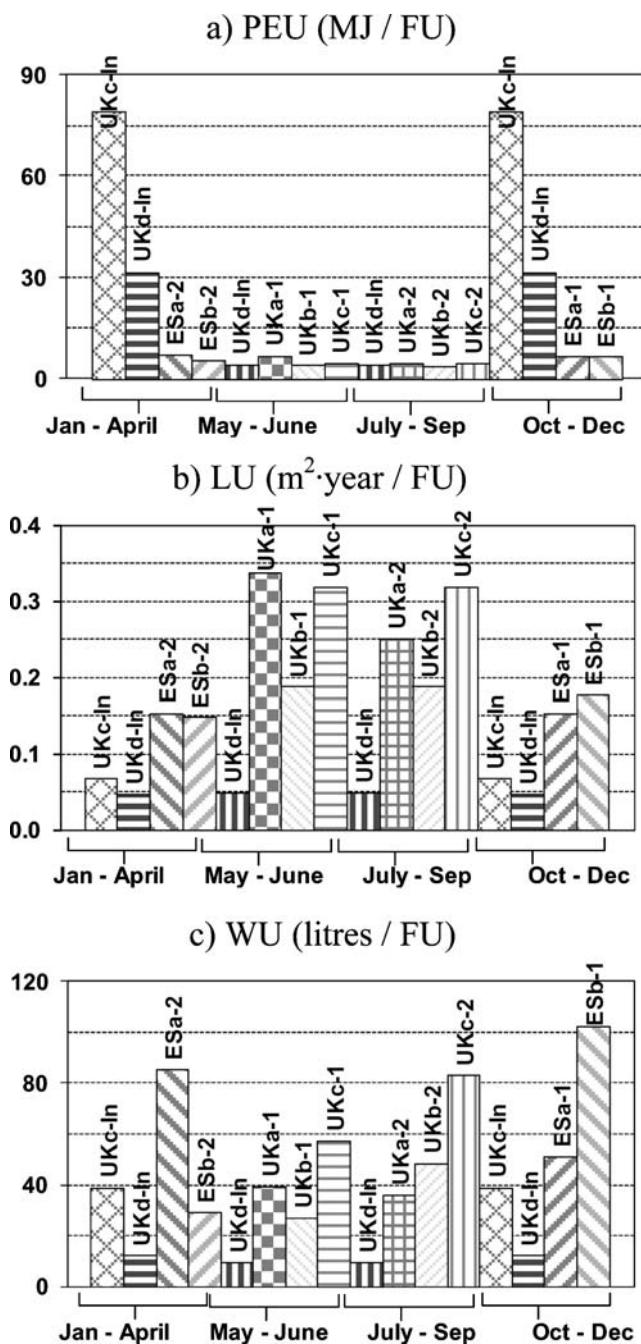


Fig. 5 Comparative results for the inventory indicators of the studied suppliers: **a** PEU (MJ/1 kg of lettuce delivered to the RDC), **b** LU (m²·year/1 kg of lettuce delivered to the RDC), **c** WU (litres/1 kg of lettuce delivered to the RDC)

main outputs from this work was clarification of the meanings of freshness, which was defined in five ways. The first and most common meaning of freshness (already identified in other studies such as Péneau et al. 2007) relates to the physiological ageing of the vegetables assessed through the senses (vision, taste, touch or smell), to food that does not show traces of deterioration or is not close to decaying. Freshness is then often equated with having

better taste, the ‘right texture/firmness’ and seasonality. The second meaning comprises a measure of both time and space in the food chain, with vegetables considered ‘fresh’ if they are not older than 2 days from the time they are picked; imported vegetables, especially from distant countries, are therefore considered less fresh than those sourced locally. The third meaning is defined by contradistinction from processed, preserved or frozen produce; thus, ‘fresh’ vegetables are those which have not been processed. This leads to a fourth meaning, as vegetables frozen within 2 h from harvest (e.g. peas, beans) may be considered by some consumers to be ‘fresher’ than unprocessed vegetables that have spent days or weeks on retail shelves. Finally, freshness was also assessed according to retail company or outlet; this is consistent with studies that illustrate the importance of the context of shopping for embedding disparate food qualities (e.g. Holloway and Kneafsey 2000). The findings also show that, in general, consumers prefer and support British produce, in this case, locally grown rather than imported lettuce. However, some consumers were able to talk about the environmental, ethical and social implications of transporting food globally and locally in quite sophisticated ways, showing that deciding on the ‘best’ option when choosing food is a complex process. Some consumers recognised that food choices are a constant and daily compromise between alternatives. A strong reaction was also found against protected cropping (specifically in polytunnels) in Herefordshire due to several factors: visual impact on the landscape; social impact due to entry of migrant workers into the local community; perceived decrease of flavour; and environmental impact, in this case specifically related to the energy used to heat greenhouses. But in general, consumers in the sample were not aware of the implications of producing food under protected systems.

Results of the focus groups and in-depth interviews suggested that the most striking seasonal variation in vegetable/salad eating was a tendency to consume more salads in the summer and more cooked vegetables in the winter. Some consumers do eat salads in the winter, but the majority reported using salads mainly in the summer and stated that this sort of substitution was not relevant to their daily lives as they tended not to eat lettuce in the winter (apart from special occasions or when eating out). Therefore, no significant insights were obtained from the sample of consumer interviews into why winter consumption of lettuce is increasing in the UK nor from the focus groups into why alternatives to winter lettuce are not widely considered acceptable. Lettuce and cabbage were generally not considered equivalent products, as they demand different methods of preparation and cooking and have different taste and texture. Coleslaw was the predominant home-prepared winter salad not containing lettuce. Thus,

from a technological point of view, it may be acceptable to compare lettuce in winter with alternative crops that would provide similar nutritional and/or functional value; however, consumer meanings and attitudes must be taken into account when interpreting such comparisons.

4 Discussion

Based on the seven case study farms and associated alternative supply chains, the results obtained for GWP and PEU clearly show higher contributions for indoor lettuce production over winter in the UK when compared to lettuce imported from Spain. The results obtained for indoor production are of the magnitude reported by van Hauwermeiren et al. (2007) for cabbage lettuce production in heated greenhouses in The Netherlands (1.25 kg CO₂-eq/kg, heating exclusive). When compared with summer outdoor production in the UK, lettuce imported from Spain only displays a slight increase in PEU and no clear difference in GWP or AP.

The most significant differences between indoor UK production and imported field lettuce produced in winter lie in LU and particularly WU. However, WU needs further characterisation to capture the significance of water scarcity in the various farm locations (e.g. Milà i Canals et al. 2009). Also, the specific effects of occupying the same area of land with arable land or with a glasshouse need to be incorporated in any further assessment (e.g. Milà i Canals et al. 2007b).

However, it is noteworthy that the variation in some key variables between farms in the same country is at least as large as that between farms in the different countries. For this reason, no generalisations can be made as to which country has the most environmentally benign production systems. The same effect was reported by Milà i Canals et al. (2006) for apples in different New Zealand regions. This intrinsic variation at the farm level suggests that there is ample potential for improvement in both indoor and outdoor production, regardless of location, and these results need to be properly communicated to industry to guide the reduction of environmental impacts.

Another issue to be noted is the risk of using industry benchmarks in LCA studies. As explained above, one indoor producer participating in this study (UKd-In) reported energy use substantially below the accepted benchmark for the sector. This illustrates both the caution with which non-primary data should be used and the possibility of reducing the “carbon footprints” of consumer produce by selection of producers using best practice.

The sample of consumer interviews does not provide an insight into why winter consumption of lettuce is increasing in the UK. It appears likely that the increase in winter

consumption is driven by restaurants and food caterers (e.g. as filler in sandwiches). If this is the case, then the comparisons made in this paper would suggest that continuing the increase in imports from Spain would reduce the contribution to some of the environmental impacts (GWP, PEU) compared to an increase in UK indoor production during winter. However, it is important to note that the sample comprised residents in rural areas, and more research is needed to establish whether urban consumers share the same preferences. Salad and vegetable consumption is associated with general messages of healthy eating and therefore sensitive to social class and educational level. Sociological studies have revealed that people with higher education levels and in the higher socioeconomic groups are more concerned with what they eat and are more discriminating in their food habits, choosing what they believe to be healthier options such as salads and vegetables (Warde 1997).

However, the use of alternatives such as cabbage or chicory could be explored in more detail, since initial results suggest a potential reduction in PEU with winter cabbage when compared to Spanish lettuce. Furthermore, consideration of consumer preferences may merit analysis of a range of other alternative winter salads; indeed, LCA studies often compare alternative systems that may seem technologically equivalent, but more attention should be given to social aspects, such as consumer acceptability of alternatives. Consumer insight may also suggest unsuspected alternatives.

5 Conclusions

This paper has explored the environmental consequences of consuming lettuce year-round in the UK based on a limited sample of seven farms. Whilst the farms are not a statistically representative sample of all UK and Spanish lettuce farms, the work is notable as it does present data for individual farms rather than for an overall supply chain as often occurs in LCA studies (e.g. Jones 2002; Saunders et al. 2006; Sim et al. 2007³). Whilst recognising the small sample size, the comparative analysis of the different supply chains does suggest that seasonality can be an important variable when defining the best environmental choice of lettuce. The social analysis suggests that seasonality seems to have some significance in orienting consumers’ salads eating habits, but it also shows that consumers’ views must be considered in defining alternatives for comparison. This kind of study needs to be pursued to investigate both urban and rural consumers

³ Sim et al. do display individual data from three farms of royal gala apple in the UK, but not for the other crops analysed in the paper.

using a mixed methodology with both quantitative and qualitative components.

6 Recommendations and perspectives

One clear outcome of this study is that inter-farm variability is large, so that any comparison of products sourced from different countries must be based on a larger sample of farms. Also, comparative studies of horticultural crops should clearly define (in the functional unit) the time period when a product is consumed to determine which supply chains are relevant, as alternative supply chains may vary significantly in their environmental impacts. A clear distinction should be drawn between field- and protected-produce in each crop.

The distribution of environmental hotspots may not be consistent between different crops. Therefore, case-by-case studies are needed to establish ‘crop families’ with similar distribution of environmental impacts (e.g. ‘protected leaf vegetables’, ‘field leaf vegetables’, etc.).

Attention should be paid to the sources of information used for further studies; particularly, industry benchmarks may not be representative of actual commercial sites, as shown in this study.

Closer work with food consumption sociologists is desirable in the goal and scope definition of food LCA studies to determine what food alternatives can be fairly compared and what other considerations are needed to provide results which are meaningful to consumers.

Finally, this study reports usage of resources that are key to agricultural products: land and water. These indicators should be further characterised to consider their associated environmental impacts in order to capture the potential trade-offs between different production systems.

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